The FY-3C evaluation project: microwave sounder calibration and direct broadcast experiences

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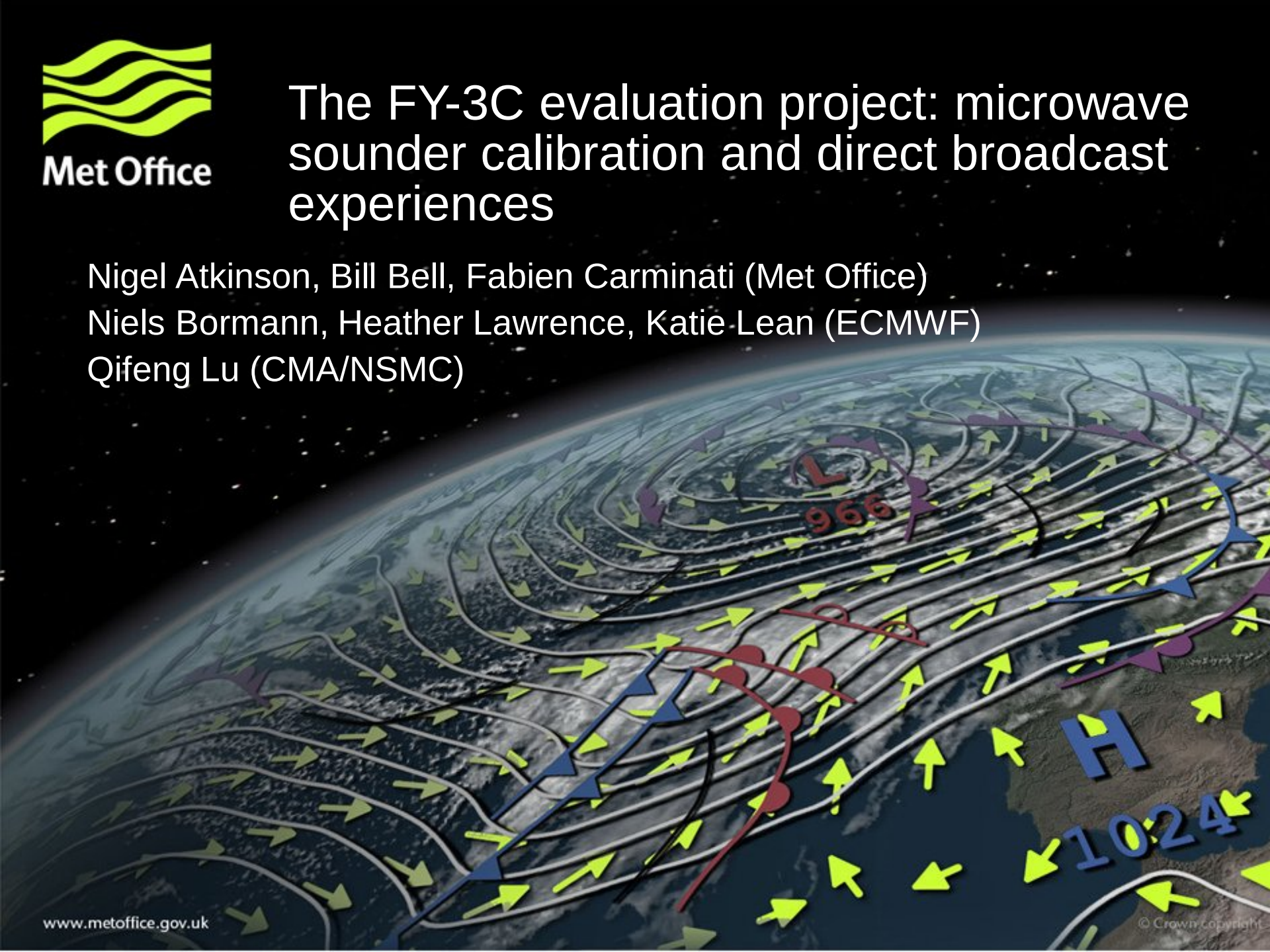
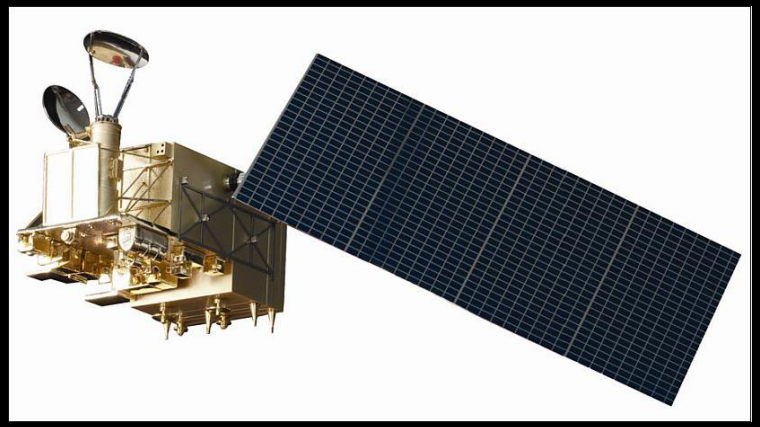


FY-3C launch 23 Sep 2013



Contents:

- Direct broadcast – experiences since ITSC-19
- Current status of FY-3C
- Evaluation of the microwave sounders

Approach to the FY-3C evaluation

- The post-launch evaluation of the FY-3C sounders was a collaborative effort:
  - CMA/NSMC (Qifeng Lu and colleagues)
  - ECMWF (Niels Bormann, Heather Lawrence, Steve English)
  - Met Office (Bill Bell, Katie Lean, Nigel Atkinson, Fabien Carminati)
- Two main strands:
  - Global data in NWP (covered by other talks)
  - Detailed assessment of the calibration – including use of DB data (this talk)
- Emphasis initially on the microwave sounders
  - Making use of previous experience with AMSU, MHS, etc.

Status at ITSC-19 (March 2014)

- First release of the DB package for FY-3C was during the conference
- Action PSWG-1: Test the FY-3C software and report back to the PSWG members

  (Nigel Atkinson and Liam Gumley)

http://satellite.cma.gov.cn/portalsite/default.aspx

Initial findings

- L-band data rate has changed for FY-3C: 4.2 → 3.9 Mbps
- X-band (for MERSI) polarisation changed RHCP → LHCP
  - These were a surprise (not announced by CMA in advance) and resulted in some delay to acquisition of data. (June 2014 at MetO)
  - The polarisation is still an issue at some stations (WMO are trying to find out which DBNet stations are affected)
- Installing and running the DB package
  - Distributed as binaries
  - Easy to install on Linux
  - Needs 64-bit platform (issue for some applications e.g. MEOS polar)
  - Processing implemented for MWTS-2, MWHS-2, IRAS, VIRR, MERSI
  - Runs OK, and quickly (~15 seconds)
  - Sometimes there is a lack of diagnostic information – e.g. initial problem with MWTS processing giving *segmentation fault* – eventually discovered that this was because the scan rate had been changed 2.667 → 5.23 seconds

FY3C package updates

Date	Version	Main Reason	Any problems?
31/3/2014	FY3CL0pp.1.0.0 FY3CL1pp.1.0.0	Initial	-
02/7/2014	FY3CL1pp.1.1.0	Update MWTS-2 scan rate	FY3C_MWHS_QC.XCONF needed modifying – to make the file bigger (weird)
15/1/2015	FY3CL1pp.1.1.2 with patch 1	Modified MWTS-2 calibration method (nonlinearity; treatment of calibration samples; land/sea sensitivity correction)	Path for new MWTS-2 data files had been hard-coded. Solution at MetO was to modify the binary.
06/2/2015	Patch 2	MWHS-2 bug fixes (wrong cal target, wrong nonlinearity coefs for some channels)	-
27/8/2015	Patch 3	MWHS-2 antenna correction implemented	Long wait – this change was implemented for global data on 16th March.

Timeline of significant events

FY-3C launch 23 Sept 2013

First release of DB package, with test data: end March 2014

MWTS-2 antenna rotation rate halved May 2014, following scan problems

Data available on CMA Portal: mid June 2014

Data distributed on EUMETCast in near real time: September 2014

MWTS-2 processing changes in Jan 2015

MWHS-2 processing changes in early Feb 2015

MWHS-2 antenna correction implemented in global data March 2015

MWTS-2 scan anomalies starting 17th Feb 2015 – no global data after that

FY-3C loss of all data from 31st May 2015 – power supply anomaly

FY-3C services resumed 30th July 2015, for MWHS-2, IRAS, MWRI, VIRR, GNOS, including partial L-band DB – not MWTS-2 or MERSI (no X-band DB)

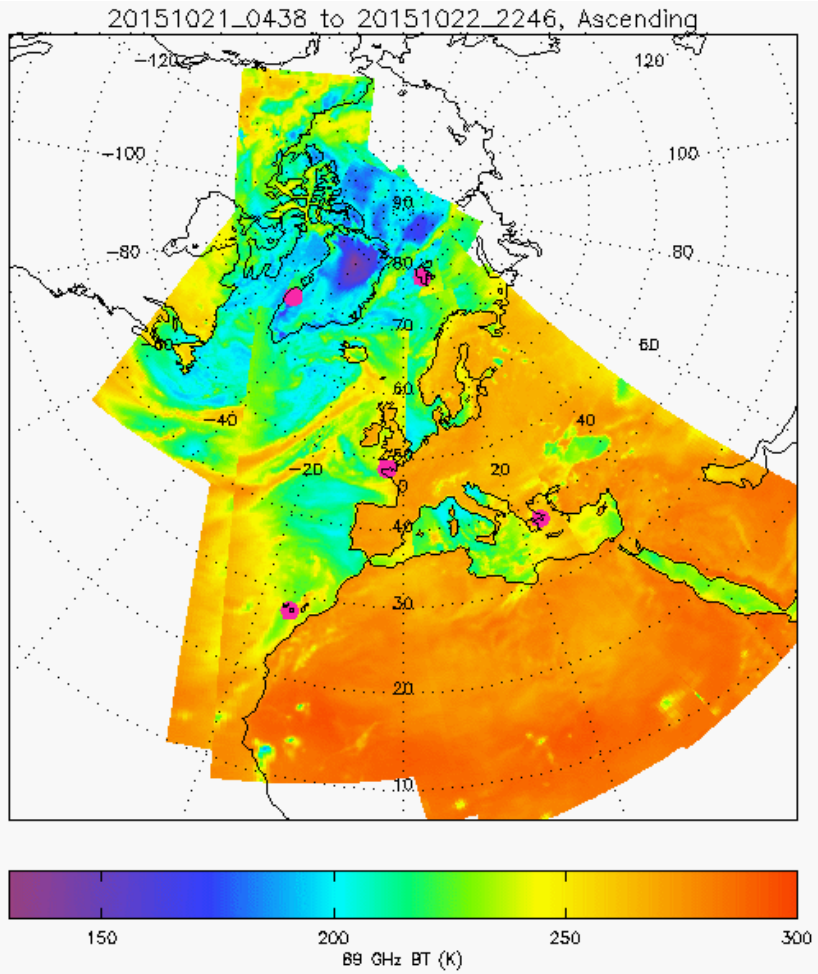
FY-3D launch – late 2016?

Summary of current FY-3C status
(start with the conclusions ... more detail later)

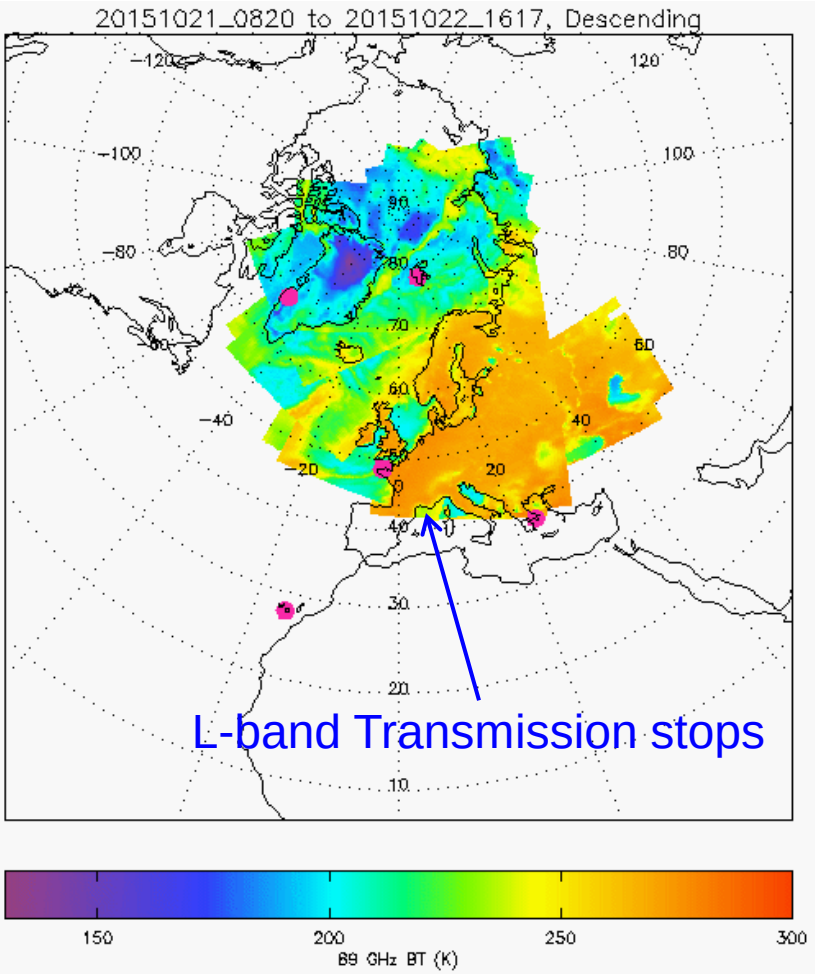
Instrument or system	Status	Comments
MWHS-2	✓	Included in new EARS-VASS service. Variable bias – needs VarBC.
MWTS-2	×	Scan mechanism problems; calibration uncertainties; inter-channel interference
IRAS	✓	Included in new EARS-VASS. Last instrument of its type.
MWRI	✓	MetO plans to evaluate in 2016. Not currently in DB package – *would benefit regional NWP?* Larger instrument planned for FY-3D
VIRR	✓	Last instrument of its type (AVHRR-like)
MERSI	×	Was working prior to power problems
GNOS	✓	Under evaluation. NRT data distribution not clear.
L-band DB	*partial*	Some passes over Europe (to support Kiruna ground station)
X-band DB	×	Not operating (to save power)

EARS-VASS service

MWHS and IRAS: 5 core EARS stations



Ascending (night)



Descending (day)

Approach to the calibration assessment for microwave sounders

- The *OBC files* (available from direct broadcast) contain all the raw counts
- The DB package includes *text files* giving external parameters
- Try to replicate the CMA calibration using external software (which we understand well)
- Also compared results with those of CMA scientists
  - During Visiting Scientist mission by NCA June 2015.

Calibration for MWHS-2 and MWTS-2

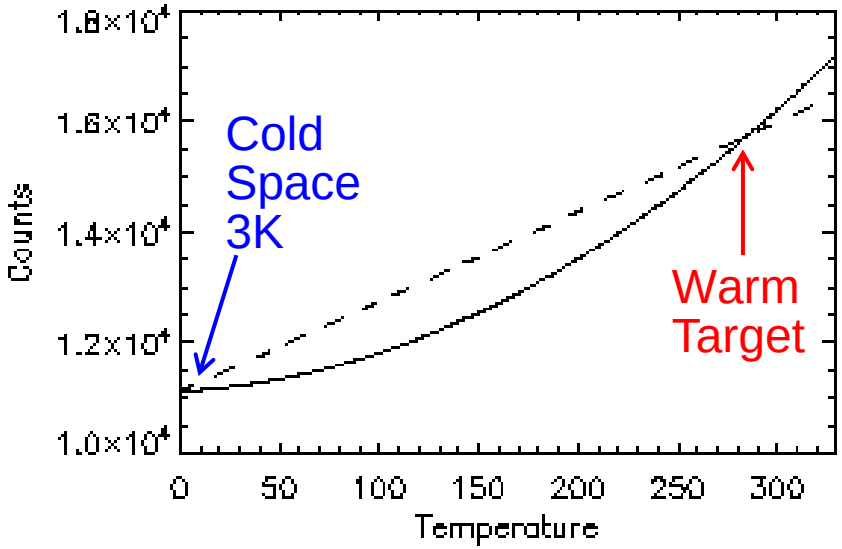
Based on the widely-used formulation used for AMSU-A and MHS

Radiance ← $R = R_{BB} + (X - X_{BB})/G + Q$ → Counts

Linear calibration plus quadratic correction

$G = (X_{BB} - X_{SP}) / (R_{BB} - R_{SP})$ *Gain computed from cold/warm views*

$Q = \mu (X - X_{BB}) (X - X_{SP}) / G^2$ *Quadratic coefficient, μ determined pre-launch*



Nonlinearity exaggeraged in the diagram!

Shows $\mu < 0$

Calibration parameters determined pre-launch

- Nonlinearity correction, μ
- Warm target bias (PRT measurement error), ΔT_W
- Cold space bias (antenna sidelobes viewing earth/satellite) , ΔT_C
- Contamination of earth view by cold space (antenna pattern correction), ΔT_i (i =1, 98)

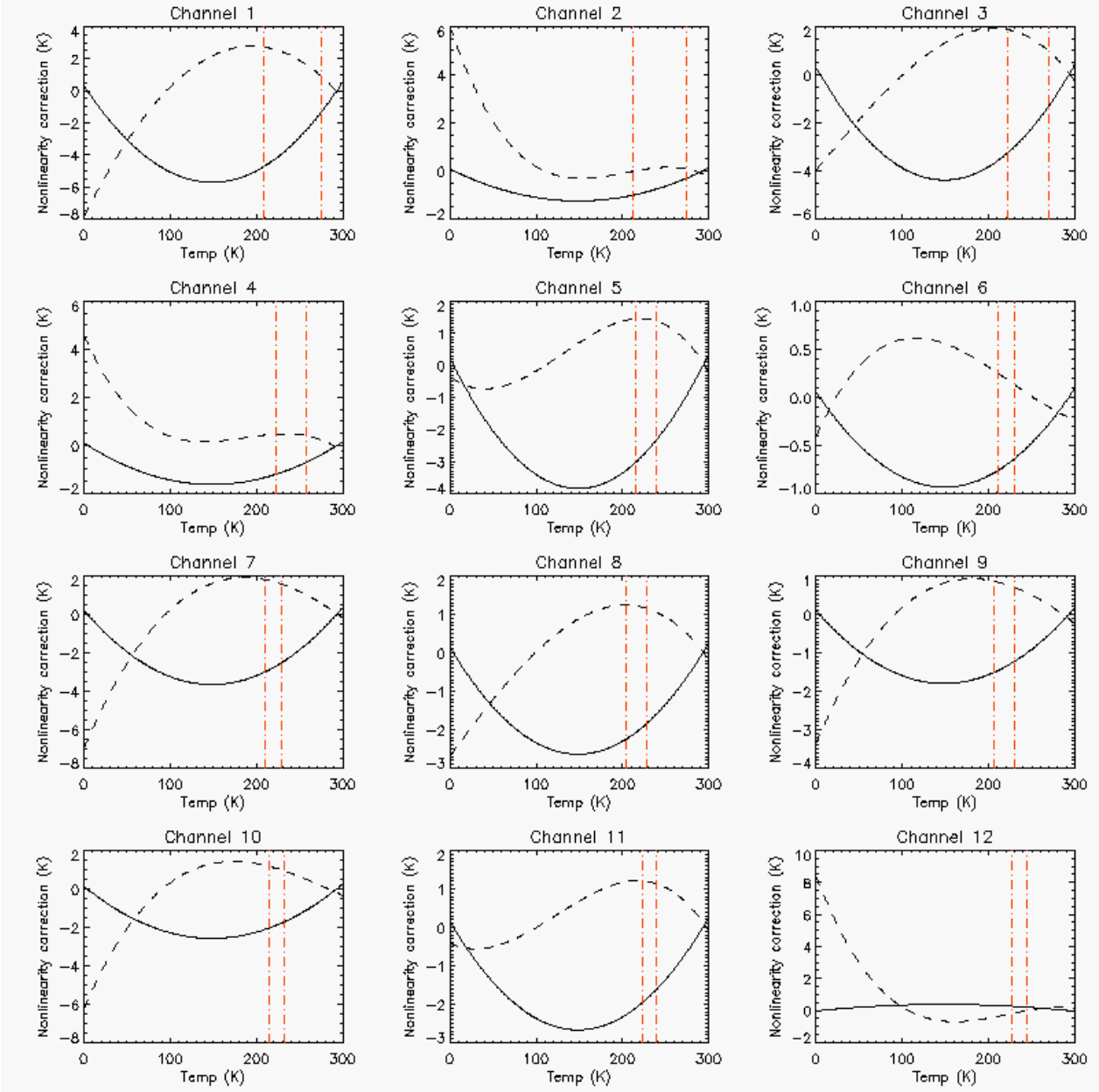
These rely on measurements – and modelling – made by the manufacturer

- Requires close dialogue between manufacturer and instrument evaluation team
- Not always achieved in practice!

Example: MWTS-2 nonlinearity

- The plots show the original nonlinearity correction (solid) and a later Jan 2015 update (dotted, cubic form)
- Clearly very different, and both are much larger than expected
- How to determine which is “right”?

Red lines show normal range of BTs for each channel

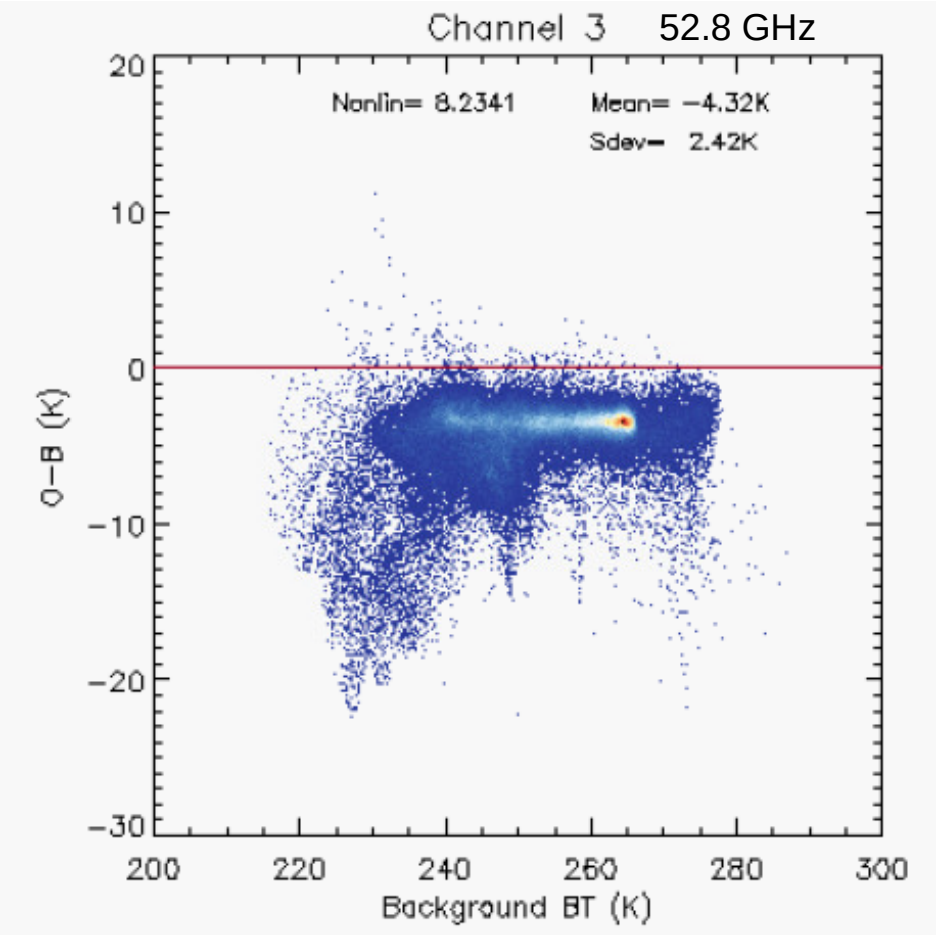


O-B investigation for MWTS-2

- Looked at the tradeoff between *nonlinearity* and *antenna correction*

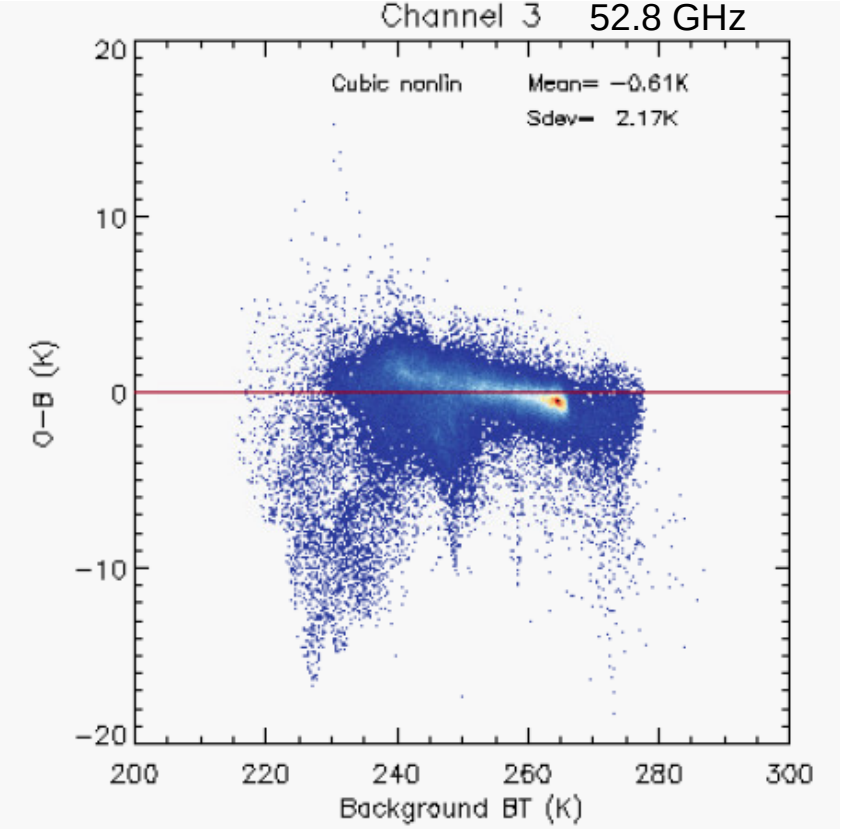
Original (2014) nonlinearity coef:
Negative bias of 3.5K

Try to adjust μ and ΔT_i to remove bias

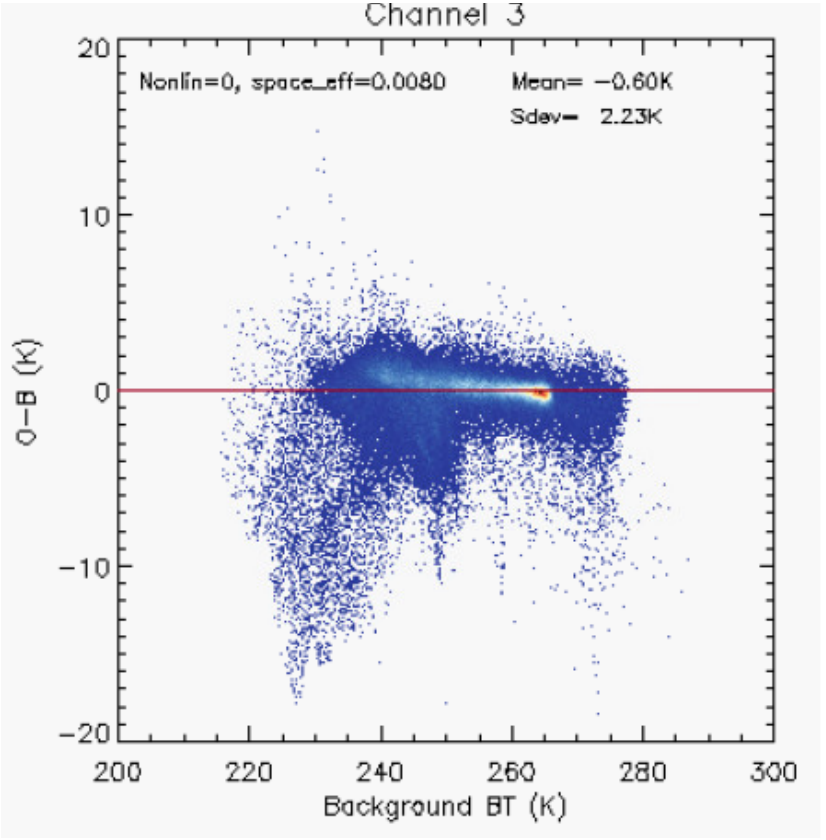


O-B for MWTS-2 (cont.)

1. CMA's "new" nonlinearity (cubic): has corrected the bias but introduced a slope



2. Nonlinearity set to *zero*, and antenna correction increased: has also corrected the bias; slope reduced

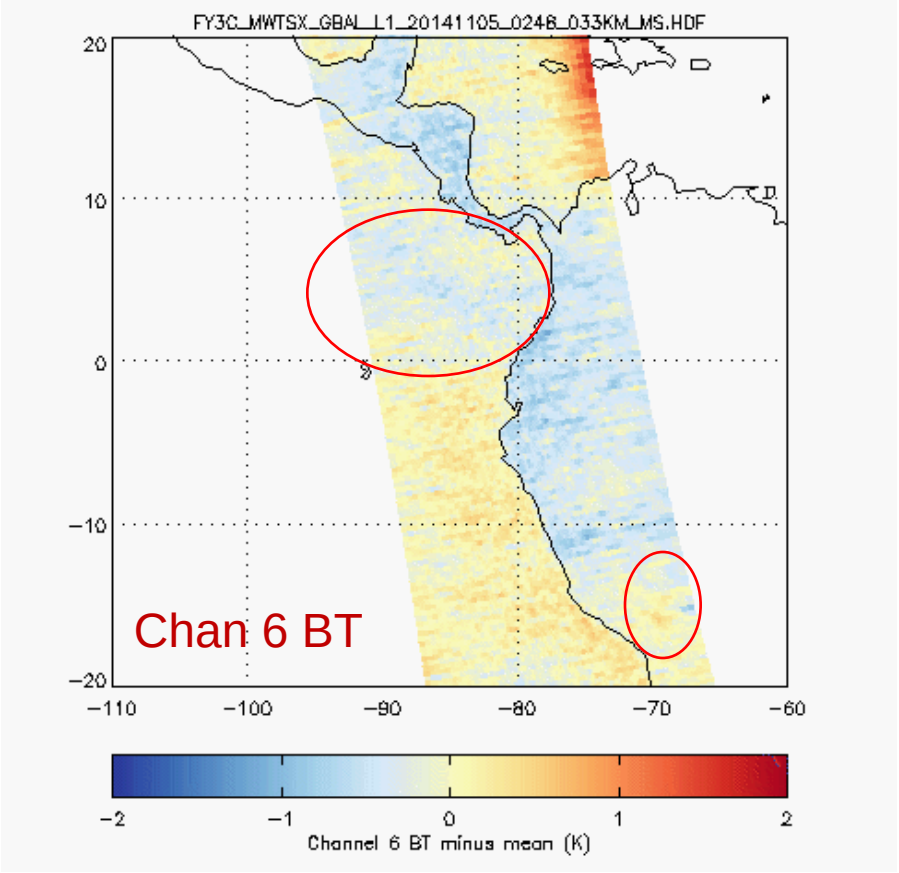


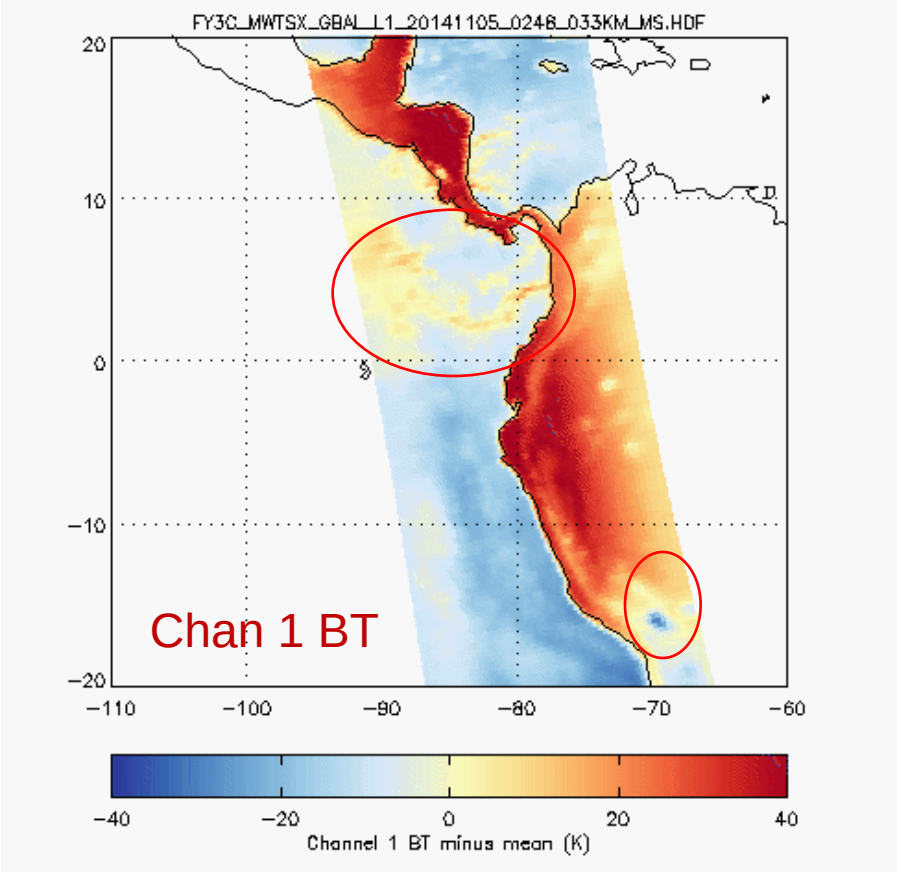
A 0.8% contribution from cold space is not unreasonable (c.f. AMSU-A)

O-B for MWTS-2 (cont.)

- In principle we could estimate antenna corrections for all channels in this way
  - ➢Which is effectively what NWP bias correction does
- But better to use pre-launch *measured* antenna pattern, if these measurements are available – and reliable
- Due to failure of MWTS-2 instrument on FY-3C we haven't pursued this study – but need to get it right for FY-3D
- There were also some problems with the software implementation – again, parked for now

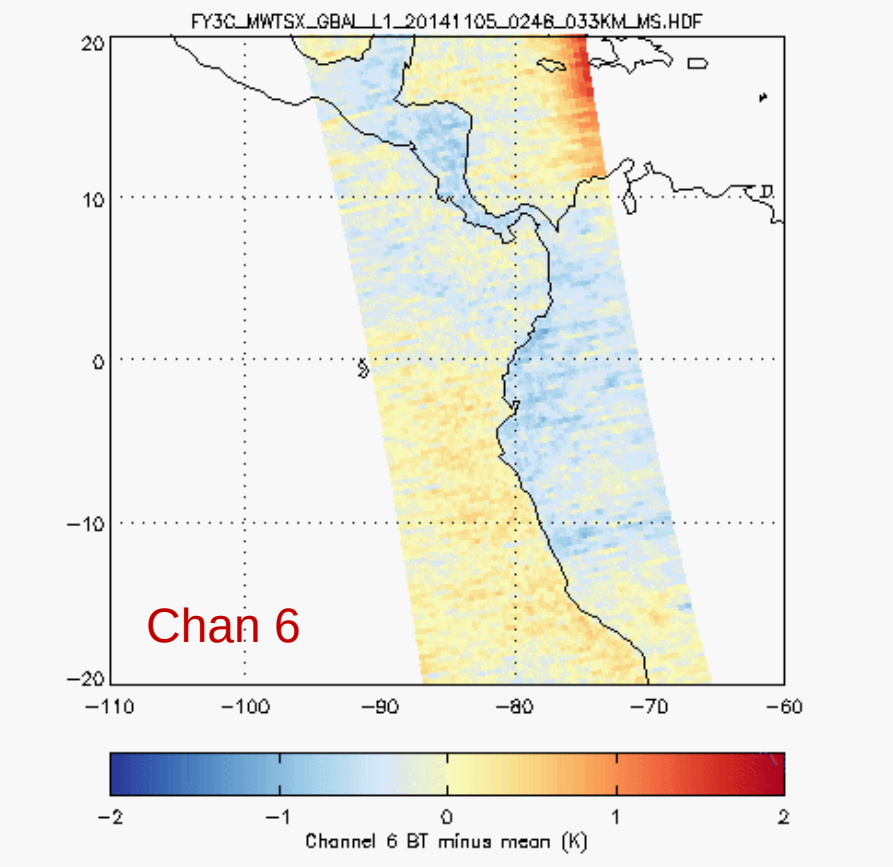
Another MWTS-2 phenomenon: Land/sea sensitivity

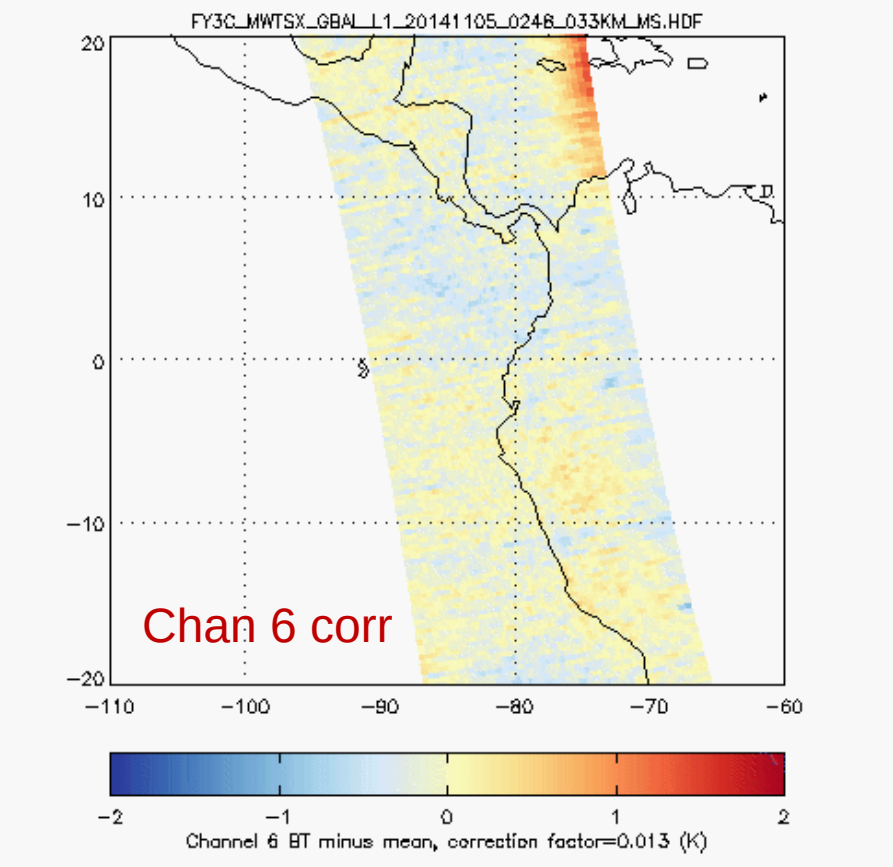




- Ch 5, 6, 7 and 8 display unphysical temp depressions over land
- These channels are not supposed to be surface sensitive
- *anti-correlation* with ch 1 – interference?
- We formulated en empirical fix – subsequently adopted by CMA in their global processor

Empirical correction





$$BT_j(\text{corr}) = BT_j + k(BT_1 - BT_j) \qquad k = 0.013 \text{ for channel 6}$$

Window channel Sounding channel

Cause?

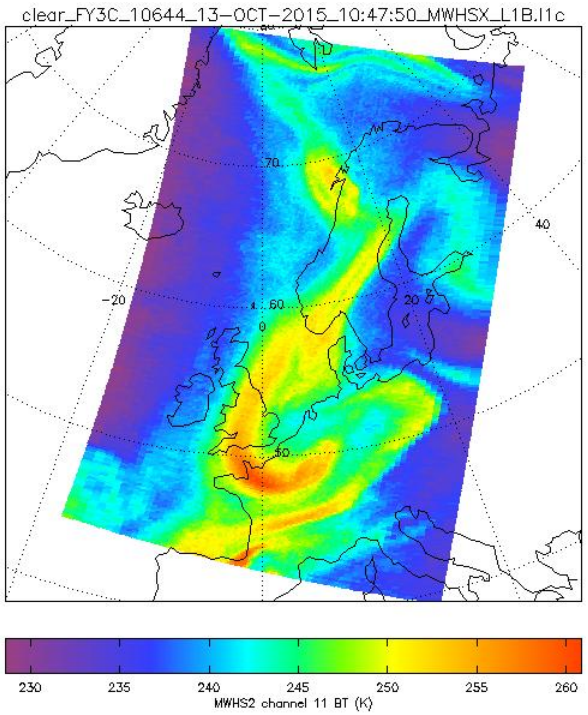
- We discussed this phenomenon with the MWTS-2 manufacturer, but no convincing explanation has been found – yet
- Looked at things like RF leakage
- Not easy to detect during pre-launch testing – because all channels view the same calibration target
  - ➢Lesson for other missions

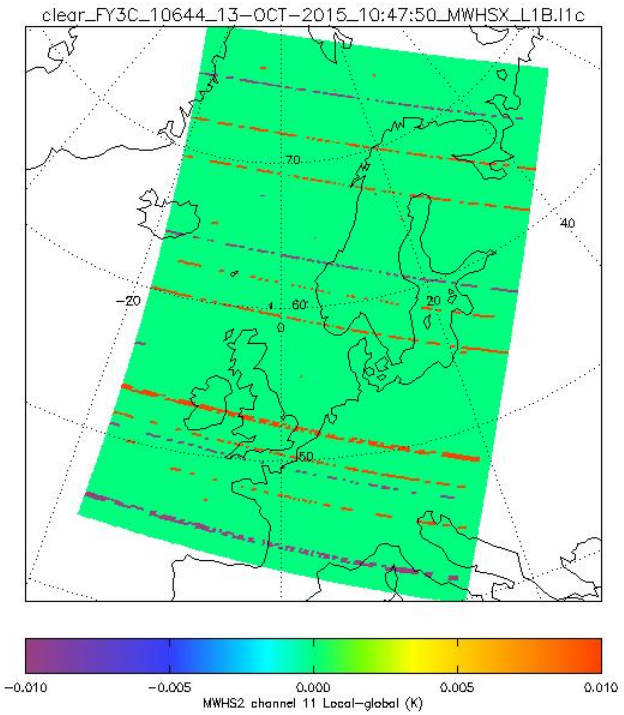
What about MWHS-2 ?

- A similar exercise was carried out for MWHS-2 – checking the calibration against independent software
- This looked good (a few bugs were fixed in the Jan 2015 update)
- Also, the global and DB package brightness temperatures are now consistent (since 27 Aug 2015)

BT
Chan 11

(183±1)



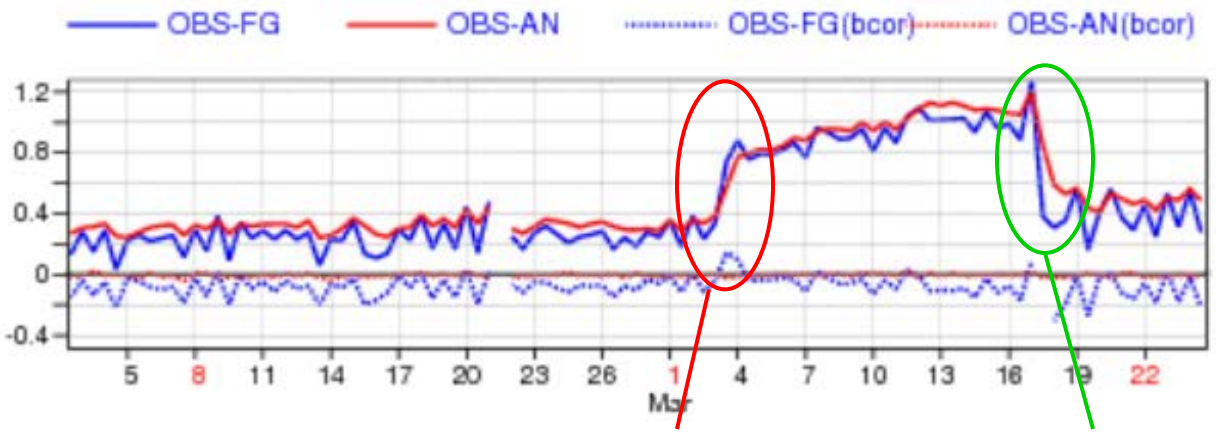


Local minus global

Consistent to <0.01K

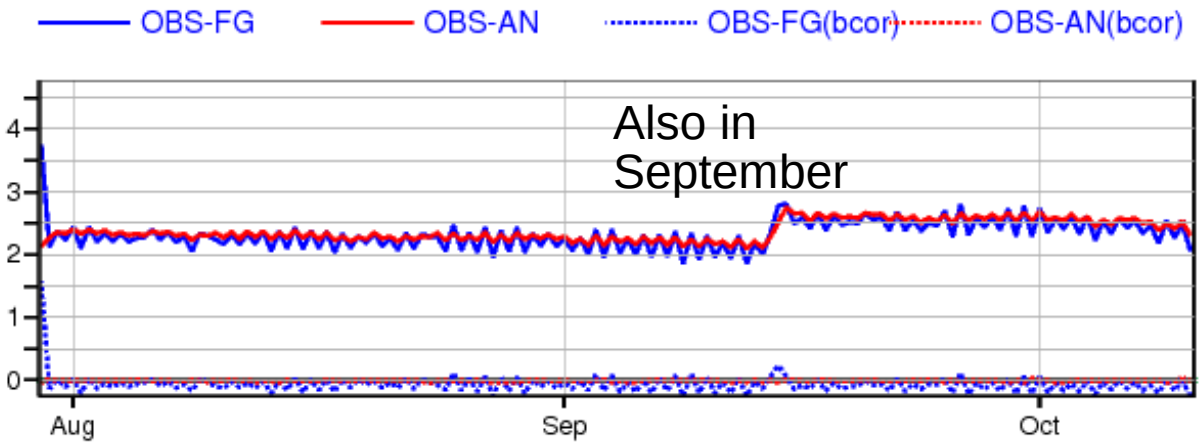
Bias changes

- ECMWF monitoring: channel 13 (183±3 GHz)



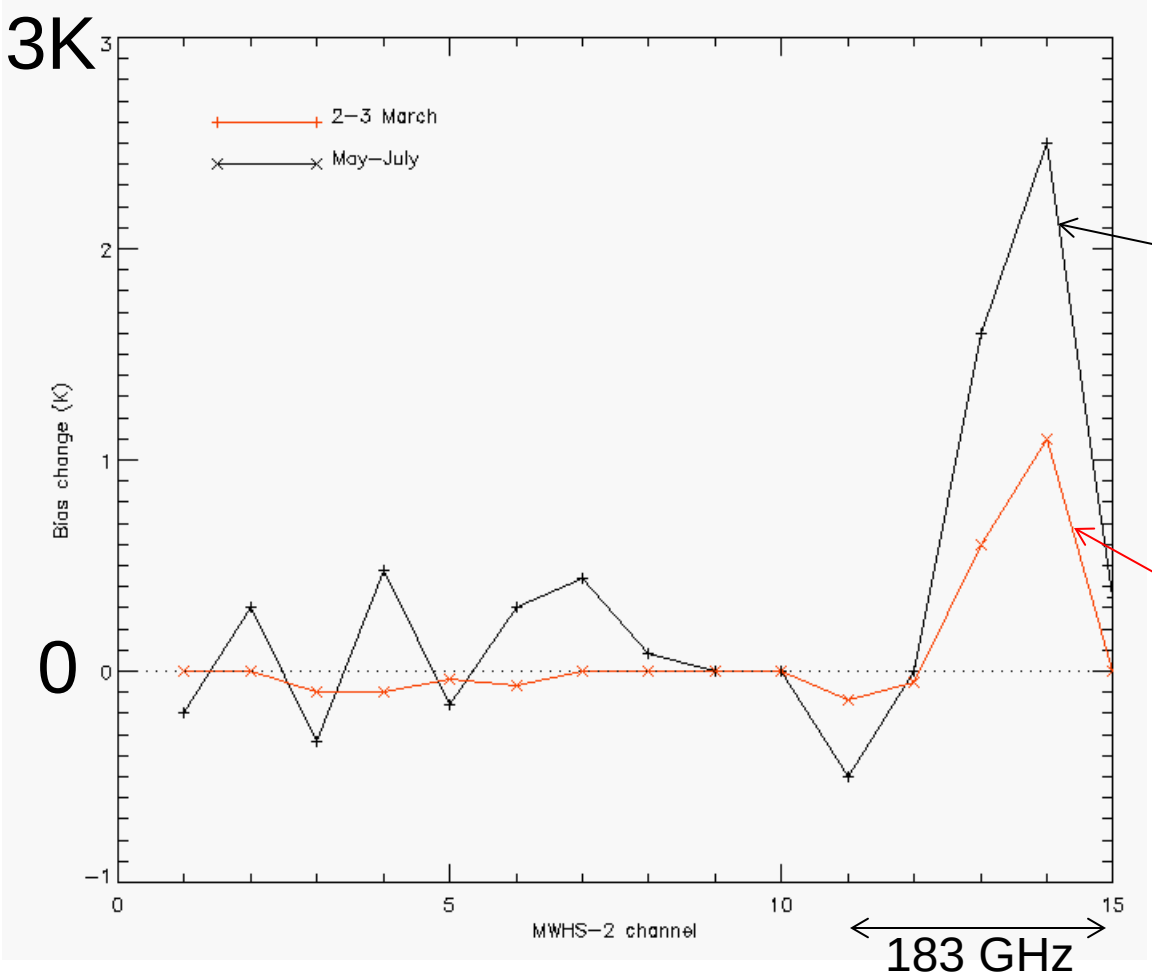
What happened here?

(This was a processing change – OK)



Bias changes (cont.)

- Bias is sensitive to instrument (platform) temperature – especially humidity channels



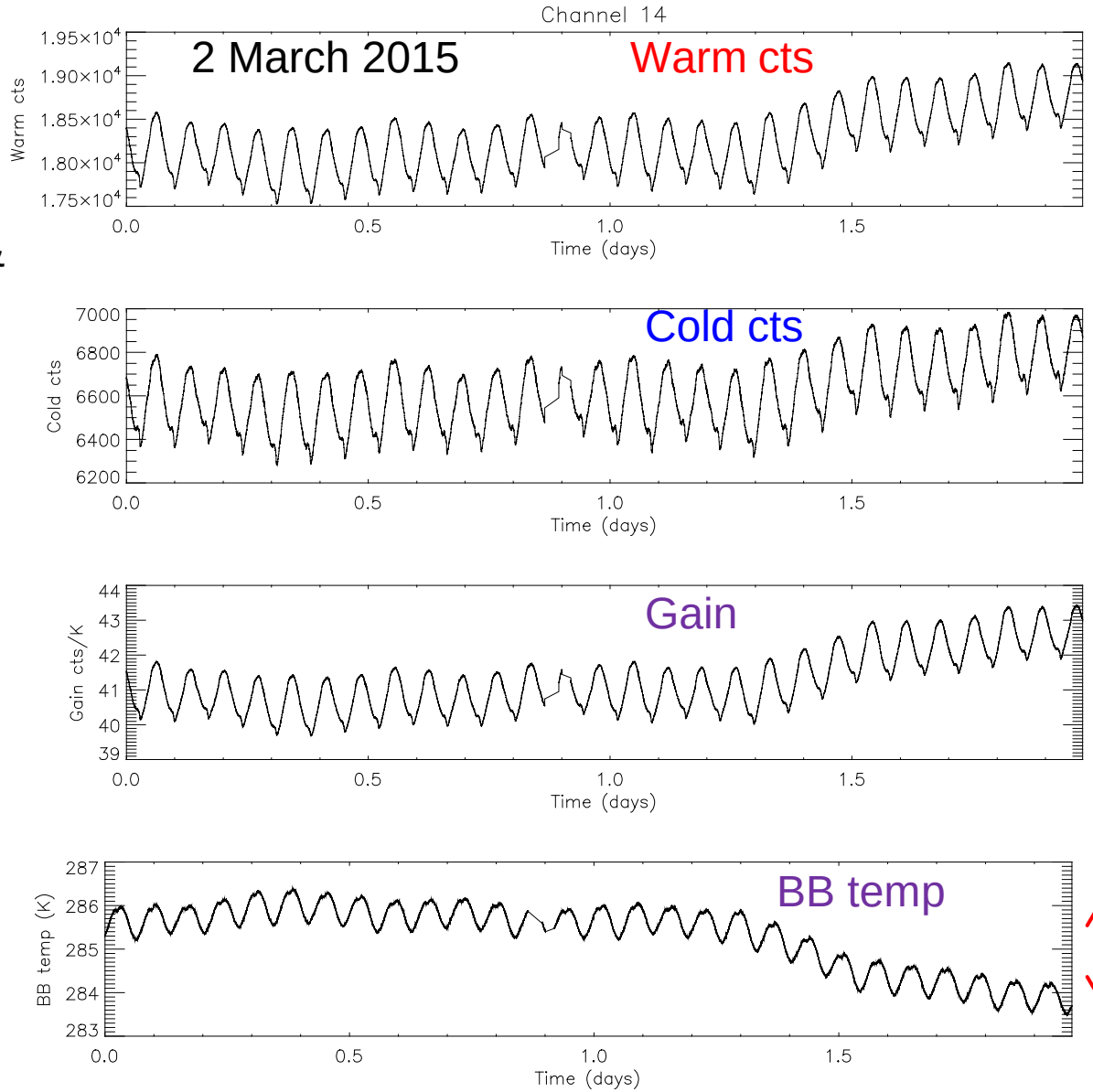
After prolonged outage due to power problems. Instrument temp is ~3.5K colder than before the outage

After sudden 2K drop in instrument temperature when MWTS-2 was powered off

Bias changes: cal counts check

Channels 13 &14:

- Slight increase in warm & cold counts when cal target temp (and instr temp) dropped by 2K
- Implies gain increase (5%)
- But why does that introduce a ~1K bias shift?
- *Unexplained!*
- Note the rather large orbital variations (larger than AMSU/MHS)



Conclusions on FY-3C

- MWHS-2 has potential, but needs VarBC to handle unexplained bias changes.
- MWTS-2 had some problems (when it was operating):
  - Reliability of scan mechanism.
  - Root cause of land-sea anomaly?
  - Some calibration parameters are unclear (e.g. nonlinearity; antenna correction)
- Met Office plans to look at MWRI in 2016. Not currently part of the DB package, but we understand that CMA might be willing to add it.
  - Would a request from ITWG help? Could be considered in WGs.
- The DB package works well, and will form part of DBNet (more in the Technical Subgroup).
- Communication of changes to central processing is important
- Close dialogue with instrument manufacturers is essential, including pre-launch

Thank you for listening!

Questions?

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FY-3C introduction

Instruments relevant to NWP:

- MWHS-2 – microwave humidity sounder (also known as MWHTS and AMAS)
- MWTS-2 – microwave temperature sounder
- IRAS – infrared atmospheric sounder (FY-3C has the last one)
- MWRI – microwave radiation imager
- GNOS – GNSS radio occultaion

Plus the imagers:

- VIRR and MERSI

Data available by direct broadcast (L-band for sounders and VIRR; X-band for MERSI)

Global sounder data distributed in NRT by EUMETSAT via EUMETCast

Direct broadcast characteristics

- From FY-3A/B Satellites to Ground Interface Control Document (updated for FY-3C, June 2014)

	FY-3A/3B	FY-3C
L-band data rate	4.2Mbps	3.9Mbps
L-band carrier freq	1704.50 MHz ± 34 kHz	1701.3 MHz
L-band polarisation	RHCP	RHCP
L-band width (zero)	5.6 MHz	5.2 MHz
X-band data rate	18.7 Mbps	18.7 Mbps
X-band carrier freq	7775.00 MHz ± 156 kHz	7780 MHz
X-band polarisation	RHCP	LHCP
X-band width (zero)	37.4 MHz	37.4 MHz

- We understand that FY-3D X-band will be RHCP and FY-3E likely to be LHCP, but to be confirmed
- For FY-3D, all instruments will be available on X-band. Likely increase in data rate. Not clear what the L-band will have.
- Only X-band for FY-3E